Evaluation of Four Inert Dusts on WHEAT as Protectants Against Insects . . . In Small Bins

Marketing Research Report No. 780

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UNITED STATES DEPARTMENT OF AGRICULTURE

PREFACE

This report presents results of one of four closely related studies concerning small-bin, intermediate-type experiments with grain treated with insecticidal materials. The first report, "Evaluation of Malathion, Synergized Pyrethrum, and a Diatomaceous Earth as Wheat Protectants . . . in Small Bins," Marketing Research Report No. 726, August 1965, presents the results of studies conducted during 1961–62. This report presents the results of studies from October 1963 to March 1965 with two diatomaceous earths and two silica aerogels, each tested at three dosage levels, and malathion at one dosage level. Three of the dusts tested—Kenite 2–I, Cab-O-Sil, and SG–68—have not been registered with the Pesticides Regulation Division, Agricultural Research Service, as grain storage treatments.

Trade or proprietary names are used in this publication solely to provide specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply either a recommendation for its use or an endorsement over comparable products.

The entomological phases of the studies were conducted at the Mid-West Grain Insects Investigations' laboratory, at Manhattan, Kans. All of the residue determinations were made by the Chemical Unit, Stored-Product Insects Research and Development Laboratory, Savannah, Ga. These are laboratories of the Stored-Product Insects Research Branch, Market Quality Research Division, Agricultural Research Service.

The chemical, milling, rheological, and baking tests were conducted at the Beltsville, Md., laboratory of the Field Crops and Animal Products Research Branch, Market Quality Research Division.

The following people contributed substantially to the subject matter research:

J. L. Wilson, Ralph Ernst, Warren E. Blodgett, and Leon H. Hendricks, all of the Stored-Product Insects Research Branch, performed some of the entomological phases of the study.

Robert M. Johnson, Dorothy M. Humphrey, Tyler F. Hartsing, Charles E. Holaday, and Doris Baker, of the Field Crops and Animal Products Research Branch, Market Quality Research Division, assisted in the chemical, milling, rheological, and baking tests. Others who performed some of these tests were Reba E. Renn, Georgia M. Gurney, Clemmer B. Marcus, Mary E. Stutzman, and Ida M. Schneider, of the Grain Division, Consumer and Marketing Service, U.S. Department of Agriculture.

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Evaluation of Four Inert Dusts on Wheat as Protectants Against Insects . . . In Small Bins

By Delmon W. La Hue and C. C. Fifield [1]

SUMMARY

Two diatomaceous earths and two silica aerogels were tested as protectants of wheat against insect infestation in 5-cubic-foot bins for 15 months. In some phases, observations were made for only 12 months.

Insect infestation readily developed in untreated 1963-crop wheat and, to a lesser degree, in untreated 1952-crop wheat from a companion field-scale bin study. Two diatomaceous earths, at dosages of 120, 210, and 300 pounds per 1,000 bushels, afforded protection in proportion to the dosage. All were superior to the standard application of 1.0 pint of premium-grade 57-percent malathion emulsifiable concentrate per 1,000 bushels of wheat. Two silica aerogels, at dosages of 15, 30, and 45 pounds per 1,000 bushels, gave generally unsatisfactory protection.

The moisture content of all grain gradually increased from about 9 percent to 12 percent during storage.

The malathion residues, which averaged 8.44 parts per million (p.p.m.) right after treatment, gradually degraded to 2.54 p.p.m. during the 15-month storage period. Severe infestations developed between the 9th and 12th months of storage in all exposed bins of malathion-treated wheat, during which time the residues degraded from 3.42 to 2.60 p.p.m. In a less disturbed bin retained for milling and baking tests and not exposed to insects, the residues remained at a higher level than in the bins that were periodically sampled.

The applications of the four inert dusts reduced the test weight of the wheat about 4 pounds per bushel, and consequently lowered the commercial grade. All samples of grain graded "weevily" after 12 months' storage.

The flour-yielding capacity and the bread-baking properties of wheat were not changed by the addition of the dusts. Sedimentation values of all samples taken after 12 months' storage showed moderate decreases, and fat acidity values showed definite increases. The mixing tolerance of flour from samples treated with diatomaceous earth did not change, but increases were noted in all other samples.

BACKGROUND AND OBJECTIVES

This report presents the findings of an experimental study to determine the efficacy of selected dosages of two diatomaceous earths and two silica aerogels applied to Hard Red Winter wheat as protectants against insect attack. This experiment was an intermediate-type study in a laboratory with 5-cubic-foot masonite bins; it was a companion study to a field-scale test with 3,250-bushel metal bins.

Five-cubic-foot cylindrical bins have been successfully used in extensive intermediate-type storage studies with corn (*4*, *6*),[2] wheat (*3*), and farmers stock peanuts (*5*).

There were two objectives of this study. One was to compare the effectiveness of selected dosages of two diatomaceous earths, Kenite 2–I® and Perma-Guard®, and two silica aerogels, Cab-O-Sil® and SG–68®, as wheat protectants with that of the standard application of malathion. The second was to determine the effect on commercial grade (*1*) and milling properties of wheat and on

[1] Entomologist and Research Chemist, respectively, with the Market Quality Research Division, Agricultural Research Service, U.S. Department of Agriculture.

[2] Italic numbers in parentheses refer to items in Literature Cited, p. 20.

baking properties of the flour milled from treated wheat.

MATERIALS AND METHODS

The experiment was conducted with Rodco variety wheat from October 1963 to March 1965. Uncleaned Hard Red Winter wheat from the 1963 crop was treated with the insecticides to be tested. Five bins of this wheat were included as untreated checks, along with five bins of untreated 1952-crop mixed composite wheat from a large field-scale test being conducted with some of the same treatments on wheat in long-term storage.

An emulsion spray was formulated from premium-grade 57-percent malathion emulsifiable concentrate (e.c.) and neutral distilled water. Five gallons of spray, containing the standard dosage of 1.0 pint of the concentrate, was applied to each 1,000 bushels of wheat. The spray was applied with a DeVilbiss HM–521 compressed-air spray gun through an aperture in the lid of a barrel while the barrel was rotating.

The diatomaceous earths were applied at rates of 120, 210, and 300 pounds per 1,000 bushels (60,000 pounds). The silica aerogels were applied at rates of 15, 30, and 45 pounds per 1,000 bushels. Characteristics of these four materials are listed in the appendix, page 20.

All these insecticides were applied to 2-bushel lots of wheat, which were then thoroughly mixed by rotating them in a steel barrel on an electric roller for 5 minutes. Immediately after a treatment of 2 lots, the 4 bushels of treated wheat were placed in a 5-cubic-foot masonite bin (fig. 1). The grain surface was immediately leveled to provide equal exposure areas in all bins. Each bin represented a treatment replicate, and all treatments were replicated five times and arranged in a random manner.

Seventy-five bins were placed in rows in a large L-shaped first-floor room of a heated dwelling house. A water-evaporating cooling unit maintained a minimum relative humidity of about 50 percent. The temperature and relative humidity were favorable for insect development throughout the storage period, although fluctuations occurred normally with extreme changes in the outside weather.

Additional bins of wheat were set up with median dosages of the diatomaceous earths and silica aerogels, the standard malathion application, and untreated 1963-crop wheat, for chemical, milling, and other tests. These extra bins were stored in an adjacent room in a more-or-less insect-free environment.

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Figure 1.—One of the small bins used in testing insecticides applied to wheat as protectants against insect attack.

Large numbers of vigorous insects, predominantly rice weevils (*Sitophilus oryzae* (L.)), confused flour beetles (*Tribolium confusum* (Jacquelin duVal)), red flour beetles (*Tribolium castaneum* (Herbst)), and lesser numbers of flat grain beetles (*Cryptolestes pusillus* (Schönherr)) and saw-toothed grain beetles (*Oryzaephilus surinamensis* (L.)) were released in the storage room 7, 21, 42, 120, and 193 days after the experiment was started. Approximately 15,000 of these insects, which had been reared on wheat, corn, sorghum, and other special culture nutriments, were uniformly scattered in the aisles and around the bins during each major introduction. Although no lesser grain borers (*Rhizopertha dominica* (F.)) had been

released, large numbers of them were observed in the infestation room after 7 months of storage. During the same period, tremendous populations of rice weevils emerged from the five untreated 1963-crop check bins. Other periods of heavy emergence of the rice weevil occurred sporadically after that.

SAMPLING

At the beginning of the test, samples of wheat taken from each bin with a grain probe directly after treatment were submitted to the Inspection Branch, Grain Division, Consumer and Marketing Service, USDA, at Kansas City, Mo., for official grade determinations. The bins of untreated 1963-crop wheat were considered as representative of the original wheat for grade comparisons. Other samples were submitted after 1 year's storage. Some information on the grading of grain containing foreign substances is included in the appendix, page 20.

Samples of grain were taken with a nonpartitioned grain trier or probe 24 hours and 1, 3, 6, 9, 12, and 15 months after treatment. The probe was inserted twice near the center and about 2 inches from the bin wall in each of the four major directions. These samples of about 2,000 grams per bin were held in sealed 1-gallon glass jars until examination. The insects were screened out by shaking the whole sample for 1 minute over a 10-mesh screen on a Rotomatic sifter. All fine dusts were immediately separated from the screenings with an 18-mesh sieve and were returned to the parent wheat sample for a 15-minute mixing period on a 33 r.p.m. wheel mixer (fig. 2).

Live and dead insects in the samples were counted for an estimation of the bin populations. The test weight and moisture content of the wheat and the percent of damaged kernels were determined. Then, four 200-gram subsamples from each bin sampling were placed in 1-pint screen-covered glass mason jars for toxicity tests. About 50 adult rice weevils, confused flour beetles, or lesser grain borers, or 10 grams of wheat infested with immature rice weevils were added to the subsamples. Mortality counts were made 21 days later. After the toxicity tests were completed,

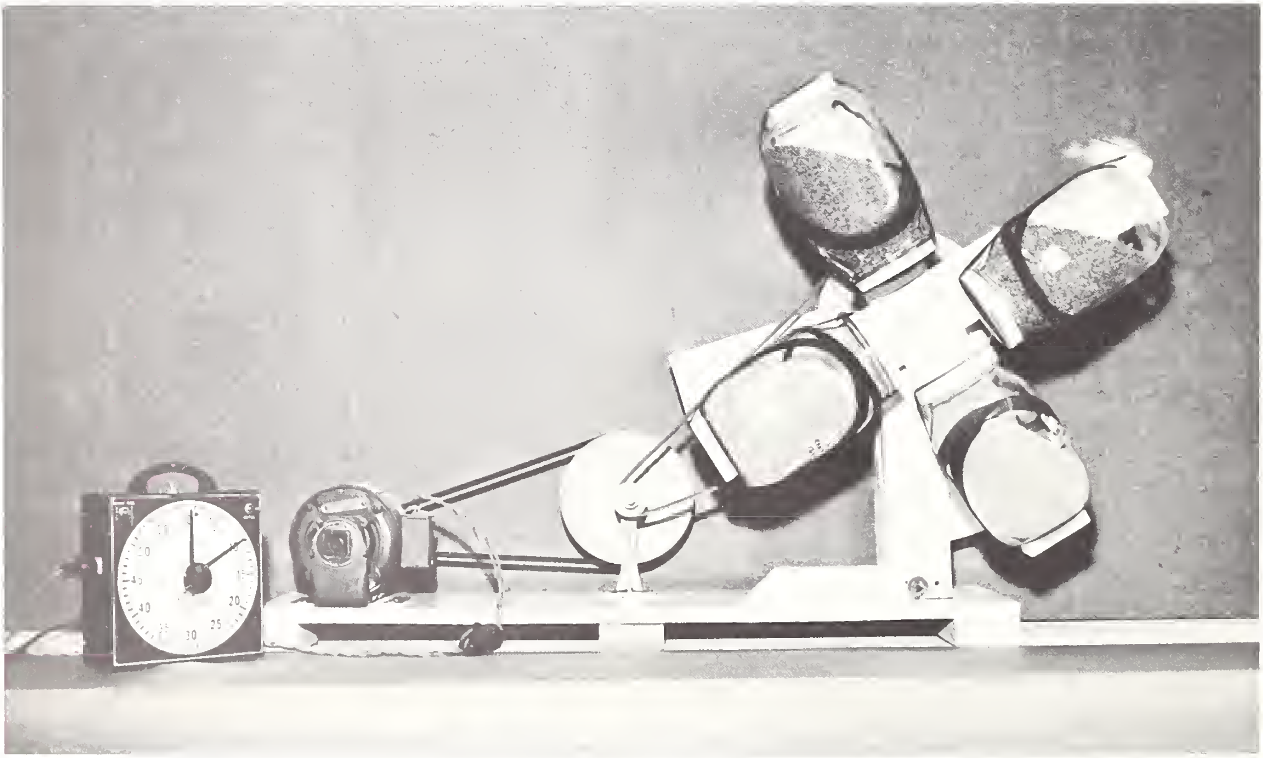

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Figure 2.—Wheel mixer used in recombining dusts with parent samples following insect counts.

the subsamples that had been exposed to adult rice weevils and lesser grain borers were retained for about 120 days for a visual assessment of damage by progeny of the insects. Samples from the malathion-treated wheat were submitted for residue determinations.

As each bin was emptied at the end of the 15-month storage period, duplicate 1-gallon samples were progressively collected from top to bottom. These samples were passed over a 10-mesh gravity screen to remove the insects, kernel bits, dust, and frass. The wheat was retained in covered jars for 42 days for a record of insect emergence. The screenings were sifted over a No. 18 sieve to separate the insect excrement or frass from the insects and kernel bits. The frass was weighed for an estimation of the extent of insect damage.

At the end of the storage period, a composited 1,000-kernel sample was taken from the gallon samples held for insect emergence, to determine the percent of kernels damaged by insects and the kernel weight loss due to insect feeding.

Fourteen-pound samples of wheat were taken immediately after treatment and again 6 and 12 months later from each of the extra bins that had been kept for chemical, milling, and other tests.

RESULTS

The moisture content of the insecticide-treated 1963-crop wheat gradually increased from an average of 9.25 percent, recorded before the treatments were applied, to a 12.42-percent average for all bins at the end of the 15-month storage period (table 1). Moisture in the untreated 1963-crop wheat increased to an average of 13.21 percent, while that in the bins of untreated 1952-crop wheat increased to 12.88 from 10.22 percent.

During the first 3 months, the relative humidity recorded at bin-top level in the storage room ranged from 91 to 25 percent. The minimum readings were of short duration, occurring only when the forced-air, gas-fired furnace was in continuous operation during extremely cold weather. After the third month, a larger evaporator (humidifier) was installed; after that the relative humidity seldom fell below 50 percent.

Malathion Residues

Initial malathion residue recoveries ranged from 8.10 to 9.20 p.p.m. Results from the different bin replicates were remarkably uniform throughout the storage period (table 2). The residues degraded gradually as the storage period lengthened, with the greatest decrease occurring during the first month. Samples of wheat scooped from the bin for chemical, milling, and other tests contained more malathion residues than wheat from the bins subjected to the many probings and exposed to a continuous movement of insects.

TABLE 1.—*Moisture content of wheat at various intervals after insecticide treatment*

Insecticide and dosage per 1,000 bushels	Before treatment	After 24 hours	After 1 month	After 3 months	After 6 months	After 9 months	After 12 months	After 15 months
Kenite 2-I:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
120 pounds	9.25	8.98	9.43	9.63	10.08	11.00	11.48	12.18
210 pounds	9.25	8.86	9.29	9.57	10.12	11.01	11.34	12.03
300 pounds	9.25	8.66	8.96	9.65	10.22	11.07	11.41	12.00
Perma-Guard:								
120 pounds	9.25	9.00	9.53	9.65	10.06	10.98	11.51	12.34
210 pounds	9.25	8.95	9.37	9.66	10.27	11.05	11.46	12.31
300 pounds	9.25	8.89	9.53	9.52	10.07	10.91	11.41	11.95
Cab-O-Sil:								
15 pounds	9.25	8.96	9.29	9.78	10.98	11.02	13.35	13.47
30 pounds	9.25	8.74	9.44	9.65	10.80	10.86	12.68	12.36
45 pounds	9.25	8.67	9.42	9.67	10.92	10.85	12.57	11.85
SG-68:								
15 pounds	9.25	9.35	9.48	10.06	11.04	11.11	12.98	13.06
30 pounds	9.25	8.91	9.36	9.83	10.97	11.03	12.52	12.99
45 pounds	9.25	8.97	9.43	9.68	10.84	11.04	12.30	12.24
Malathion, 57 pct. e.c., 1 pint	9.25	9.29	10.29	10.19	11.31	11.33	12.10	12.74
Untreated 1963-crop check	9.25	9.39	9.99	10.58	11.54	12.61	12.89	13.21
Untreated 1952-crop check	10.22	10.30	10.34	10.70	11.63	12.02	12.53	12.88

TABLE 2.—*Malathion residues recovered from wheat by chemical analyses at various intervals after treatment* [1]

Bin number	Initial malathion deposit	After 1 month	After 3 months	After 6 months	After 9 months	After 12 months	After 15 months
	P.p.m.	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
10	8. 10	6. 90	4. 20	4. 80	3. 20	2. 50	2. 00
35	8. 10	(2)	4. 40	5. 20	3. 40	2. 40	2. 50
42	8. 40	5. 70	4. 40	6. 10	3. 50	3. 50	3. 10
52	9. 20	5. 40	4. 70	5. 90	3. 30	2. 50	2. 70
61	8. 40	5. 60	3. 60	5. 60	3. 70	2. 10	2. 40
Average	8. 44	5. 90	4. 26	5. 52	3. 42	2. 60	2. 54
M–B [3]	9. 40			6. 10		4. 30	3. 90

[1] Values are expressed in parts per million of the insecticide, based on actual weight of the wheat.
[2] Sample lost.
[3] Bin reserved for wheat for chemical, milling, and other tests.

Insect Populations

Insects seen crawling about in the storage room were uniformly distributed on the floor around the bins rather than on the walls and ceiling. The amount of insect excrement and other fine dusts seen around the bases of the bins indicated the extent of insect activity within the wheat. Large amounts of dust were evident, after 3 months' storage, around the bases of the bins containing the untreated 1963-crop check wheat. Small amounts of dust were quite noticeable around bins containing the low dosages of both silica aerogels. These amounts progressively increased during the remainder of the storage period. Large amounts of dust were noted around all of the bins with the silica aerogel treatments by the 12th month. Dust began to accumulate around the bins with the malathion treatment during the last 3 months of storage. Comparatively small amounts accumulated around the bins containing the untreated 1952-crop wheat, even during the last months of storage. Only trace amounts of dust were seen around the bins with the different dosages of the diatomaceous earths.

The numbers of live adult insects recovered from probe samples from all bins in the infestation room at specified intervals indicate the populations within the bins through 12 months of the storage period (table 3). After 1 month's storage, large

TABLE 3.—*Live adult insects in all probed samples of insecticide-treated wheat taken during the 12 months' storage*

Insecticide and dosage per 1,000 bushels	Insects in samples taken after—						
	24 hours	1 month	3 months	6 months	9 months	12 months	Total
Kenite 2–I:	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
120 pounds	4	14	72	13	154	478	735
210 pounds	1	1	9	1	25	150	187
300 pounds	0	2	2	3	40	178	225
Perma-Guard:							
120 pounds	3	5	72	8	132	894	1, 114
210 pounds	1	0	20	8	60	619	708
300 pounds	1	2	11	1	22	321	358
Cab-O-Sil:							
15 pounds	5	399	472	80	3, 089	11, 173	15, 218
30 pounds	1	77	55	20	1, 315	9, 969	11, 437
45 pounds	0	5	28	7	368	3, 087	3, 495
SG–68:							
15 pounds	5	442	964	431	4, 900	7, 067	13, 807
30 pounds	1	48	371	81	1, 336	8, 347	10, 184
45 pounds	0	14	50	45	215	4, 306	4, 630
Malathion, 57 pct. e.c., 1 pint	0	0	55	99	495	4, 884	5, 533
Untreated 1963-crop check	4	828	1, 821	1, 278	9, 777	16, 994	30, 702
Untreated 1952-crop check	3	297	1, 515	375	4, 988	6, 529	13, 707

numbers of several species of insects were found in all of the bins containing untreated 1963-crop wheat, and fewer numbers were recovered from the samples of untreated 1952-crop wheat and wheat treated with the silica aerogels at 15 pounds per 1,000 bushels. Insect infestation did not develop in the 1952-crop nearly as readily as in the 1963-crop wheat.

The comparatively small number of live insects in wheat treated with the diatomaceous earths throughout the storage period may have been a result of killing action, of repellency, or a combination of both.

Tremendous populations of insects were found in samples from the 15- and 30-pound applications of the silica aerogels after 9 months' storage and from the 45-pound applications after 12 months' storage.

Malathion residues, which ranged from 3.20 to 3.70 p.p.m. 9 months after treatment and from 2.10 to 3.50 p.p.m. after 3 months' additional storage, did not prevent the establishment of insect infestations in these bins. After 12 months' storage, large populations were found in samples treated with malathion.

Many thousands of dead rice weevils accumulated around the bases of bins of malathion-treated wheat, and the top layers of wheat in these bins were darkened with the many dead insects—conditions not found with any other treatment.

Although the insects entering the many bins were not counted, it was noted that large numbers of rice weevils and flour beetles congregated on the upper rim of the bins treated with the diatomaceous earths and silica aerogels rather than entering the wheat in the bins. In direct contrast, fewer insects were seen on the rims of bins containing untreated wheat and wheat treated with malathion.

The insect counts in probed samples show that the diatomaceous earths resisted the development of insect infestations more successfully than the silica aerogels at dosages used. During the 8th to 12th months of storage, large numbers of newly emerged insects moved out of the bins of the untreated 1963-crop check and the wheat treated with the low dosage of the silica aerogels. This undoubtedly increased the numbers of live insects found in samples from bins treated with diatomaceous earths, which have a relatively slow killing action. During this same period, many rice weevils were seen entering the bins of wheat treated with malathion. The cumulative repellent action of the four inert materials in 60 of the 75 bins in the test may be responsible for the large numbers of insects, both live and dead, found in the wheat treated with malathion, which is known to be nonrepellent.

Toxicity Studies

Mortality of the adult insects was determined after 21 days' exposure to insecticide-treated wheat. Live progeny were counted 42 days after the adult mortality readings were made. Mortality of the rice weevils and numbers of their F_1 progeny in the wheat infested with the immature forms was recorded after 56 days.

During the bioassay studies conducted 24 hours after treatment, excellent kills of adult rice weevils were obtained with all treatments, except the 15-pound application of Cab-O-Sil and the 15- and 30-pound applications of SG–68 (table 4). Kills of confused flour beetles, lesser grain borers, and immature rice weevils were less spectacular (tables 5, 6, and 7).

Applications of the diatomaceous earths and malathion continued to be very effective against the lesser grain borer, both life stages of the rice weevil, and, to a lesser degree, confused flour beetles after 1 month's storage. A loss in the effectiveness of the silica aerogels after 1 month was quite evident.

The effectiveness of the diatomaceous earths gradually lessened as the storage period was extended; however, kills of the test insects or suppressions of progeny development were acceptable. A definite loss in the effectiveness of malathion residues was noted after the 9-month observations.

Although adult rice weevils were more susceptible to the insecticides than the lesser grain borers, more rice weevil progeny developed during comparable periods in these observations.

Comparatively small differences were found between the effectiveness of the two diatomaceous earths. Excellent kills of the confused flour beetles occurred throughout the storage period with both materials at the two highest rates of application.

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TABLE 4.—*Adult rice weevils: Mortality after 21 days' exposure to insecticide-treated wheat and subsequent emergence of the F_1 progeny 42 days after infestation* [1]

Insecticide and dosage per 1,000 bushels	Period between treatment and infestation of wheat													
	Immediate		1 month		3 months		6 months		9 months		12 months		15 months	
	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny
	Percent	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*
Kenite 2–I:														
120 pounds	100	2.0	100	5.6	95.3	4.6	100	6.0	94.5	27.4	79.7	47.8	83.0	54.0
210 pounds	100	2.6	100	3.4	100	.2	100	1.4	99.6	11.6	89.8	20.6	87.0	41.2
300 pounds	100	4.2	100	1.4	100	0	100	0	99.6	5.4	95.6	19.0	88.7	19.6
Perma-Guard:														
120 pounds	100	3.6	98.5	17.0	99.6	7.4	100	10.2	92.0	41.0	57.4	142.2	54.9	144.6
210 pounds	100	5.2	100	1.9	100	.6	100	3.2	99.0	17.0	86.4	42.8	79.8	54.2
300 pounds	100	2.0	100	6.6	100	0	100	.6	99.0	2.2	92.9	7.2	87.3	8.4
Cab-O-Sil:														
15 pounds	28.2	136.0	8.2	303.2	1.9	280.0	10.2	56.8	1.3	484.0	19.9	470.0	15.9	482.8
30 pounds	98.4	20.0	46.9	107.8	82.5	103.6	90.6	30.6	9.1	255.4	14.8	470.6	14.0	441.2
45 pounds	99.6	1.0	71.4	63.8	97.3	64.8	98.8	17.8	75.9	74.2	20.7	504.6	17.0	420.8
SG–68:														
15 pounds	3.6	152.0	4.7	213.6	1.5	156.4	4.6	217.6	3.1	711.6	10.0	368.6	8.6	759.9
30 pounds	80.0	37.2	13.9	134.4	10.7	87.8	22.0	152.4	1.8	492.2	11.4	484.2	11.0	258.0
45 pounds	99.3	3.1	66.8	63.4	76.0	21.2	93.3	36.2	18.0	227.6	20.5	362.0	10.6	513.2
Malathion, 57 pct. e.c., 1 pint	100	0	100	0	100	0	99.6	1.4	96.1	29.0	72.9	205.2	74.5	169.6
Untreated 1963-crop check	9.3	240.8	1.2	379.2	.6	257.6	.7	240.2	25.6	476.6	21.6	186.2	3.2	206.0
Untreated 1952-crop check	3.9	133.6	.4	354.4	.7	59.6	9.1	27.0	2.5	233.8	27.2	87.6	9.2	305.2

[1] Average of 5 replications.

TABLE 5.—*Confused flour beetles: Mortality after 21 days' exposure to insecticide-treated wheat and subsequent emergence of the F_1 progeny 42 days after infestation* [1]

Insecticide and dosage per 1,000 bushels	Period between treatment and infestation of wheat													
	Immediate		1 month		3 months		6 months		9 months		12 months		15 months	
	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny
	Percent	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*
Kenite 2–I:														
120 pounds	95.7	0.2	72.5	0	94.0	0.2	97.7	0	90.1	0.4	16.3	0.2	21.2	0.4
210 pounds	99.2	0	96.5	0	100	0	99.6	0	99.2	0	91.6	0	91.2	0
300 pounds	100	0	99.2	.2	100	0	100	0	100	0	98.0	0	98.0	0
Perma-Guard:														
120 pounds	92.2	0	51.2	0	84.7	0	93.6	0	79.8	0	39.2	1.0	28.5	1.6
210 pounds	99.6	0	96.7	0	100	0	99.6	0	96.5	0	92.9	.2	83.3	.4
300 pounds	99.6	0	98.4	0	100	0	100	0	99.6	0	99.6	0	96.6	0
Cab-O-Sil:														
15 pounds	3.5	0	5.6	0	1.9	.2	2.3	1.4	2.0	1.6	9.4	3.2	4.8	4.6
30 pounds	61.2	0	19.1	0	17.2	0	17.3	0	1.5	1.0	4.5	2.4	2.4	2.0
45 pounds	99.2	0	65.5	0	74.6	0	73.1	0	38.1	0	1.2	1.2	1.2	.6
SG–68:														
15 pounds	4.7	0	4.0	0	6.3	.2	1.1	0	.8	1.4	5.2	3.2	3.9	3.0
30 pounds	37.7	.2	3.6	0	14.3	.2	3.1	0	2.0	.6	2.2	2.8	1.9	2.4
45 pounds	88.5	0	10.5	0	30.0	.2	34.2	0	16.8	0	2.4	2.4	2.0	1.6
Malathion, 57 pct. e.c., 1 pint	99.3	0	88.1	0	92.1	0	65.4	0	31.0	0	8.8	.6	7.6	1.4
Untreated 1963-crop check	2.0	1.4	3.5	3.2	4.1	1.0	.4	1.4	1.2	1.2	3.3	5.4	1.2	7.2
Untreated 1952-crop check	1.2	0	2.3	0	4.7	0	0	1.6	2.7	1.2	.4	2.2	0	6.6

[1] Average of 5 replications.

TABLE 6.—*Lesser grain borers: Mortality after 21 days' exposure to insecticide-treated wheat and subsequent emergence of the F_1 progeny 42 days after infestation* [1]

Insecticide and dosage per 1,000 bushels	Period between treatment and infestation of wheat													
	Immediate		1 month		3 months		6 months		9 months		12 months		15 months	
	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny
Kenite 2-I:	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*
120 pounds	94.7	0	98.2	3.8	71.5	5.4	74.1	2.4	60.5	2.8	27.5	6.4	31.1	7.2
210 pounds	96.9	1.2	98.9	.6	87.2	2.2	94.5	.6	83.3	1.0	67.9	1.6	59.4	2.0
300 pounds	96.2	0	97.6	.2	96.7	.2	94.1	0	91.1	.8	88.0	0	68.2	.4
Perma-Guard:														
120 pounds	85.3	.8	72.2	1.6	38.9	6.6	37.0	2.4	42.4	8.0	53.2	6.0	38.9	9.8
210 pounds	88.7	.4	91.4	.4	70.5	1.8	83.6	1.2	71.6	.8	64.4	3.6	48.9	5.8
300 pounds	96.3	0	94.4	0	90.9	.4	93.2	.8	93.3	0	92.0	.8	79.1	3.0
Cab-O-Sil:														
15 pounds	58.5	.4	36.1	6.4	11.9	11.2	13.6	8.6	10.7	11.4	45.3	6.8	34.1	10.2
30 pounds	81.1	2.8	57.5	1.6	25.7	2.2	11.6	5.4	9.7	5.2	39.1	8.6	34.0	13.2
45 pounds	96.6	.8	72.2	1.4	52.0	1.4	26.7	3.0	26.9	1.0	30.3	11.6	23.0	13.4
SG-68:														
15 pounds	34.8	3.0	27.6	2.6	9.3	8.4	19.4	12.0	19.8	43.0	60.5	14.4	27.7	24.8
30 pounds	72.5	2.8	32.6	3.0	11.8	7.2	20.9	11.6	9.7	21.2	53.8	10.8	30.3	16.0
45 pounds	90.5	1.0	60.8	3.2	38.9	2.4	25.4	4.8	13.3	7.2	46.1	8.4	19.4	13.6
Malathion, 57 pct. e.c., 1 pint	100	0	93.7	0	99.2	0	99.6	0	86.6	3.4	59.6	6.2	50.2	11.0
Untreated 1963-crop check	28.2	25.4	11.1	5.4	4.4	17.6	6.7	15.2	29.0	34.8	24.6	67.2	19.4	114.0
Untreated 1952-crop check	17.3	16.4	18.7	18.8	6.9	17.8	2.7	8.8	12.5	5.6	27.7	21.4	31.0	21.4

[1] Average of 5 replications.

TABLE 7.—*Rice weevils: Total mortality and number of progeny living in insecticide-treated wheat 56 days after infestation of wheat by immature weevils* [1]

Insecticide and dosage per 1,000 bushels	Period between treatment and infestation of wheat													
	Immediate		1 month		3 months		6 months		9 months		12 months		15 months	
	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny	Mortality	Progeny
	Percent	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*	*Number*
Kenite 2–I:														
120 pounds	97.7	2.2	93.3	4.8	94.2	8.8	98.0	1.2	90.6	5.8	98.0	3.4	95.0	9.4
210 pounds	99.2	.8	96.5	2.8	97.7	3.0	99.0	.6	98.8	.6	100	0	99.5	.8
300 pounds	98.2	1.0	98.5	1.4	99.5	.6	98.1	1.2	98.8	.6	100	0	100	0
Perma-Guard:														
120 pounds	84.7	10.4	84.2	18.0	89.9	14.6	97.1	1.8	88.0	7.0	86.2	36.0	76.1	62.6
210 pounds	97.1	2.0	95.0	4.8	98.1	2.6	100	0	97.5	1.2	99.3	1.2	92.2	11.2
300 pounds	100	0	87.2	9.0	99.4	.8	100	0	99.6	.2	100	0	100	0
Cab-O-Sil:														
15 pounds	14.8	177.0	1.1	315.4	4.3	315.4	6.9	56.4	14.8	1,305.0	24.3	481.8	22.2	509.6
30 pounds	54.7	44.0	26.5	120.8	22.2	175.6	56.9	20.0	11.6	834.4	23.8	529.2	16.4	474.4
45 pounds	70.2	27.4	39.5	82.2	50.9	86.4	91.9	3.4	30.6	211.6	22.0	396.4	15.8	403.2
SG–68:														
15 pounds	8.4	206.0	4.6	295.6	2.8	514.6	1.6	198.6	19.3	1,716.8	21.2	413.8	13.7	581.2
30 pounds	49.4	61.4	8.7	197.8	3.1	364.4	10.9	665.6	15.9	1,228.6	18.4	450.2	14.1	545.0
45 pounds	74.3	19.4	32.3	94.6	16.7	218.2	65.5	14.2	10.1	554.8	16.5	461.8	18.8	447.2
Malathion, 57 pct. e.c., 1 pint	100	0	100	0	98.9	1.4	100	0	96.0	4.0	52.8	241.6	51.5	208.4
Untreated 1963-crop check	8.6	127.8	1.1	577.0	7.1	536.2	.9	435.8	20.0	815.2	13.3	182.8	10.6	164.2
Untreated 1952-crop check	2.4	330.6	3.2	308.4	15.7	239.2	.8	47.0	18.7	1,024.6	20.2	73.6	16.3	239.8

[1] Average of 5 replications.

Insect Emergence

The extent of the infestations that had become established in the bins of wheat is shown by the emergence of insects and the resultant progeny damage (table 8) in samples taken as the bins were emptied. Relatively large numbers of rice weevils emerged from the wheat treated with the diatomaceous earths, as a result of eggs deposited by the females before the slow action of these dusts brought about their deaths. Only a slight amount of damage was inflicted by the progeny when the samples were held for visible damage ratings. Progeny in the 1963-crop check and in wheat treated with the silica aerogels caused considerable damage. The progeny damage to the 1952-crop check was not as great as was expected from the large numbers of progeny that emerged and was about equal to the damage in the malathion-treated wheat. Infestations of the lesser grain borer, although not introduced artificially into the storage room, had become firmly established in all bins. The diatomaceous earths and malathion were most effective in controlling the infestations.

Insect Damage

The extent of insect damage to the wheat in storage depended largely on the amount of residues remaining on the grain and the number and species of insects present. An insect may inflict discernible damage to the kernels before it is killed by chemical residues or other means. Damage to the inside of the kernels causes losses in weight. If the inside damage is extensive, the kernels may break into fragments during handling. All such types of damage were observed in this test, and some variation was recorded in the percent of damaged kernels, the kernel weight losses and the test weights.

Various methods were used to estimate insect damage to the wheat. The loss in commercial grade may in part be considered an important indication because it directly affects the price received for the grain. Other methods of estimating damage done by the insects were measuring the amount of insect frass and calculating the losses in pounds per bushel, the percentage of kernels damaged by insects, and the kernel weight losses.

TABLE 8.—*Average emergence of live adult insects and progeny damage per gallon of 10-gallon samples of insecticide-treated wheat taken 15 months after start of test and held 42 days*

Insecticide and dosage per 1,000 bushels	Emergence					Visible progeny damage [1]
	Rice weevils	Flour beetles	Lesser grain borers	Others	Total	
	Number	*Number*	*Number*	*Number*	*Number*	*Rating*
Kenite 2–I:						
120 pounds	307. 7	2. 7	20. 0	0	330. 4	0. 6
210 pounds	165. 4	1. 7	4. 6	0	171. 7	. 3
300 pounds	145. 6	. 9	7. 4	. 2	154. 1	0
Perma-Guard:						
120 pounds	593. 6	4. 3	14. 1	0	612. 0	1. 1
210 pounds	316. 1	2. 3	43. 2	0	361. 6	. 4
300 pounds	208. 1	1. 1	12. 0	0	221. 2	0
Cab-O-Sil:						
15 pounds	1, 224. 7	3. 8	30. 9	1. 3	1, 260. 7	3. 3
30 pounds	948. 7	1. 3	18. 6	0	968. 6	3. 1
45 pounds	738. 6	3. 0	16. 7	0	758. 3	2. 1
SG–68:						
15 pounds	2, 081. 7	11. 1	30. 1	. 5	2, 123. 4	3. 8
30 pounds	1, 772. 5	21. 0	28. 8	. 4	1, 822. 7	3. 8
45 pounds	1, 245. 1	3. 3	10. 3	. 1	1, 258. 8	2. 7
Malathion, 57 pct. e.c., 1 pint	713. 7	6. 7	10. 9	0	731. 3	1. 3
Untreated 1963-crop check	1, 140. 7	54. 9	1, 081. 9	24. 9	2, 302. 4	4. 0
Untreated 1952-crop check	849. 0	10. 8	129. 3	1. 2	990. 3	1. 3

[1] Damage ratings code: 0= no visible infestation; 1= slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4= ascending numbers of insects and corresponding amount of insect frass; 5= large infestation with great amounts of insect frass and spoilage of grain.

In relation to dosage, the ranking of the treatments for their effectiveness in preventing insect damage was fairly consistent. In every test, all dosages of the diatomaceous earths were more effective than any dosage of the silica aerogels. In every test except one, the diatomaceous earths protected the wheat more effectively than the malathion. In weight per bushel, malathion-treated wheat was highest. The diatomaceous earths lowered the commercial grade of the wheat at the time they were added, but not as much as the silica aerogels did. However, wheat treated with diatomaceous earths maintained its grade better than wheat with the other treatments or without treatment.

The 15- and 30-pound dosages of SG–68 were the poorest treatments in all tests. The untreated 1963-crop check lots were by far the most heavily damaged by every measurement except weight per bushel. The untreated 1952-crop wheat was consistently less damaged than wheat treated with the low and medium dosages of both silica aerogels.

The weights of the fine dusts, primarily insect frass sifted from the terminal 1-gallon samples, also indicated the amount of physical damage to the kernels of wheat during storage. Only small amounts of this waste material were recovered from wheat treated with the diatomaceous earths. The least amounts came from the larger dosages (table 9). Relatively small amounts of dust were found in the samples from the untreated 1952-crop wheat. Relatively large amounts of dusts were recovered from the lowest dosage of the silica aerogels, but not so much from the higher dosages. A little more dust was recovered from the malathion-treated samples than from samples with the lowest dosage of the diatomaceous earths and a little less than from those with the highest dosage of the silica aerogels. It was much less than from the untreated 1963 wheat.

The applications of the diatomaceous earths and the silica aerogels initially reduced the test weight of the wheat by about 4 pounds per bushel. Dust adhering to the kernels affected the settling and nestling qualities and reduced the number of kernels per given volume. This measurable loss lowered the grade of the wheat.

No significant test weight losses from insect damage occurred in wheat treated with any dosage of the diatomaceous earths (table 10). Significant losses from insect damage were re-

Table 9.—*Weight of insect frass per gallon sample of wheat 15 months after treatment with insecticide*

Insecticide and dosage per 1,000 bushels	Average [1]	Range
	Grams	*Grams*
Kenite 2–I:		
120 pounds	17. 37	11. 3 to 25. 0
210 pounds	14. 52	8. 7 to 19. 6
300 pounds	11. 59	6. 9 to 16. 4
Perma-Guard:		
120 pounds	21. 64	17. 1 to 26. 9
210 pounds	16. 24	13. 1 to 20. 8
300 pounds	11. 79	7. 8 to 16. 4
Cab-O-Sil:		
15 pounds	95. 43	72. 1 to 126. 0
30 pounds	62. 09	48. 4 to 78. 9
45 pounds	29. 98	20. 1 to 42. 9
SG–68:		
15 pounds	107. 32	89. 3 to 128. 6
30 pounds	84. 49	63. 6 to 111. 1
45 pounds	32. 99	21. 1 to 54. 2
Malathion 57 pct. e.c., 1 pint	24. 56	11. 9 to 36. 4
Untreated 1963-crop check	205. 11	102. 7 to 371. 9
Untreated 1952-crop check	35. 93	26. 7 to 49. 4

[1] Five replications of each treatment.

corded in wheat treated with the silica aerogels, especially the smaller dosages. The weight loss of wheat protected by malathion amounted to about 7.1 percent or about 4.1 pounds per bushel. The untreated 1963-crop check lost about 11.7 pounds per bushel, or about 19.9 percent, but the untreated 1952-crop wheat lost only 5.5 pounds, or 9.2 percent.

The weight of undamaged whole kernels passing over a 10-mesh screen averaged 0.0288 and 0.0290 grams, respectively, for the 1963- and 1952-crop wheat. Samples of 1,000 kernels from each bin were examined under magnification to determine the percent of kernels damaged. The weights of the damaged and undamaged kernels were recorded, and calculations were made of the kernel weight loss (table 11).

The diatomaceous earths gave far greater protection to the wheat than the silica aerogels. Kernel damage and calculated weight losses between comparable dosages of the two diatomaceous earths differed only slightly. Although 30.28 percent of the kernels treated with malathion were damaged, the weight loss was 9.64 percent, which is only slightly greater than the losses with the lower dosage of the two diatomaceous earths. Damage to the wheat treated with the silica aerogels was heavy, and differences due to dosage were quite distinct. The 1963-crop check wheat

TABLE 10.—*Test weights of wheat per bushel at given intervals following insecticide applications*

Insecticide and dosage per 1,000 bushels	Before treatment	After treatment	After 1 month	After 3 months	After 6 months	After 9 months	After 12 months	After 15 months	Loss (−) or gain (+)	
									After treatment	Total
Kenite 2–I:	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
120 lb	58. 68	54. 68	54. 26	54. 46	54. 42	54. 36	54. 14	54. 08	−0. 60	−4. 60
210 lb	58. 68	54. 48	54. 50	54. 52	54. 32	54. 44	54. 28	54. 40	−. 08	−4. 28
300 lb	58. 68	54. 52	54. 54	54. 54	54. 26	54. 26	54. 28	54. 24	−. 28	−4. 44
Perma-Guard:										
120 lb	58. 73	54. 60	54. 62	54. 80	54. 56	54. 72	54. 32	54. 50	−. 10	−4. 23
210 lb	58. 73	54. 56	54. 62	54. 70	54. 34	54. 72	54. 42	54. 60	+. 04	−4. 13
300 lb	58. 73	54. 16	54. 50	54. 44	54. 52	54. 74	54. 44	54. 48	+. 32	−4. 25
Cab-O-Sil:										
15 lb	58. 68	54. 66	54. 62	54. 40	54. 14	53. 96	50. 58	46. 86	−7. 80	−11. 82
30 lb	58. 68	54. 30	54. 48	53. 84	53. 52	53. 78	51. 72	50. 16	−4. 14	−8. 52
45 lb	58. 68	54. 42	54. 48	53. 88	54. 00	53. 84	53. 16	52. 00	−2. 42	−6. 68
SG–68:										
15 lb	58. 73	54. 66	54. 62	54. 42	54. 14	53. 76	50. 04	42. 88	−11. 78	−15. 85
30 lb	58. 73	54. 52	54. 52	54. 48	53. 82	54. 48	51. 86	47. 96	−6. 56	−10. 77
45 lb	58. 73	54. 62	54. 34	54. 28	53. 68	54. 40	52. 94	52. 20	−2. 42	−6. 53
Malathion, 57 pct. e.c. 1 pint	58. 73	58. 78	58. 34	57. 88	57. 84	57. 96	55. 68	54. 62	−4. 16	−4. 11
Untreated 1963 crop check	58. 68	58. 58	58. 62	58. 26	58. 58	53. 76	48. 78	46. 92	−11. 66	−11. 76
Untreated 1952 crop check	59. 59	59. 64	59. 54	59. 40	59. 34	57. 94	54. 66	54. 14	−5. 50	−5. 45

TABLE 11.—*Kernel damage and calculated weight loss of insecticide-treated wheat after the 15-month test period*

Insecticide and dosage per 1,000 bushels	Kernels damaged	Weight loss [1]
Kenite 2–I:	*Percent*	*Percent*
120 pounds	10. 08	8. 51
210 pounds	8. 02	4. 98
300 pounds	7. 88	4. 02
Perma-Guard:		
120 pounds	10. 28	7. 14
210 pounds	6. 30	4. 17
300 pounds	5. 08	4. 37
Cab-O-Sil:		
15 pounds	58. 78	22. 26
30 pounds	52. 40	18. 62
45 pounds	37. 68	14. 00
SG–68:		
15 pounds	74. 06	29. 09
30 pounds	62. 96	23. 81
45 pounds	39. 82	14. 89
Malathion, 57 pct. e.c., 1 pint	30. 28	9. 64
Untreated 1963-crop check	91. 70	49. 58
Untreated 1952-crop check	47. 80	17. 48

[1] Weight of undamaged 1963- and 1952-crop whole kernels averaged 0.0288 and 0.0290 grams, respectively.

was heavily damaged: 91.7 percent of the kernels were damaged, and the kernel weight loss was 49.58 percent. The untreated 1952-crop wheat had only 47.8 percent of the kernels damaged, and the weight loss was 17.48 percent. This difference between the two check lots of wheat was substantiated in all of the other measurements of damage. It suggests that some unknown, innate quality of the 1952-crop wheat protected it from insects.

In addition to the data obtained in the bioassays, estimates were made of the extent of damage caused by internal infestations by the progeny of rice weevils and lesser grain borers used in the bioassays. For this purpose, the samples were held for 120 days after the bioassays were completed. The insect damage to each sample was estimated at 75, 90, and 120 days after the adult insects had been screened out during the bioassays. Tables 12 and 13 show estimates of visible damage from infestations that had developed in the bioassayed samples 120 days after the periodic samplings taken during 12 months' storage.

Very little damage was seen in the samples that had been treated with diatomaceous earths and stored up to 9 months before sampling. At 9 months the wheat was susceptible to some damage by the lesser grain borer, and after 12 months by the rice weevil also. Damage to wheat treated with Perma-Guard was slightly greater

TABLE 12.—*Visible damage by rice weevil progeny after toxicity tests of samples of insecticide-treated wheat collected at specified intervals during storage*

Insecticide and dosage per 1,000 bushels	Damage observed 120 days after a storage period of [1]—					
	24 hours	1 month	3 months	6 months [2]	9 months	12 months
Kenite 2-I:	*Rating*	*Rating*	*Rating*	*Rating*	*Rating*	*Rating*
120 pounds	0	0	0	0	0. 2	0. 8
210 pounds	0	0	0	0	0	. 2
300 pounds	0	0	0	0	0	. 2
Perma-Guard:						
120 pounds	0. 2	0. 4	0	0	. 2	1. 6
210 pounds	0	0	0	0	. 2	1. 4
300 pounds	0	0	0	0	0	. 8
Cab-O-Sil:						
15 pounds	4. 4	5. 0	4. 6	4. 6	([3])	([3])
30 pounds	2. 8	3. 8	3. 4	4. 2	([3])	([3])
45 pounds	0	2. 0	1. 6	3. 6	([3])	([3])
SG-68:						
15 pounds	4. 6	5. 0	5. 0	4. 8	([3])	([3])
30 pounds	2. 6	5. 0	4. 2	5. 0	([3])	([3])
45 pounds	. 4	4. 6	2. 2	2. 6	([3])	([3])
Malathion, 57 pct. e.c. 1 pint	0	0	0	0	. 4	3. 6
Untreated 1963-crop check	4. 8	5. 0	5. 0	---------	([3])	([3])
Untreated 1952-crop check	4. 8	5. 0	4. 4	3. 8	3. 8	3. 8
1963-crop check [4]	. 2	3. 8	3. 6	5. 0	5. 0	5. 0
1952-crop check [4]	. 2	1. 8	2. 6	3. 4	3. 4	3. 4

[1] Damage ratings code: 0=no visible infestation; 1=slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4=ascending numbers of insects and corresponding amount of insect frass; 5=large infestation with great amounts of insect frass and spoilage of grain.

[2] The samples stored for 6 months were rated 135 days, instead of 120 days, after storage.

[3] Samples not retained due to heavy infestations shown in toxicity reading.

[4] Samples not exposed to insects during storage.

TABLE 13.—*Visible damage by lesser grain borer progeny after toxicity tests of samples of insecticide-treated wheat collected at specified intervals during storage*

Insecticide and dosage per 1,000 bushels	Damage observed 120 days after a storage period of [1]—					
	24 hours	1 month	3 months	6 months [2]	9 months	12 months
Kenite 2-I:	*Rating*	*Rating*	*Rating*	*Rating*	*Rating*	*Rating*
120 pounds	0. 6	0. 6	1. 8	1. 2	1. 6	2. 2
210 pounds	. 2	. 4	. 8	1. 0	. 2	. 8
300 pounds	0	0	0	0	0	. 2
Perma-Guard:						
120 pounds	1. 6	2. 0	2. 4	1. 6	2. 2	2. 0
210 pounds	. 8	. 8	1. 2	1. 2	1. 8	1. 8
300 pounds	0	0	0	0	0	1. 2
Cab-O-Sil:						
15 pounds	2. 6	4. 2	4. 0	4. 2	([3])	([3])
30 pounds	1. 4	2. 8	2. 6	2. 8	([3])	([3])
45 pounds	0	1. 8	. 6	1. 6	([3])	([3])
SG-68:						
15 pounds	3. 4	4. 6	3. 6	4. 6	([3])	([3])
30 pounds	1. 8	4. 0	2. 6	3. 8	([3])	([3])
45 pounds	. 4	1. 0	1. 8	1. 6	([3])	([3])
Malathion, 57 pct. e.c. 1 pint	0	0	0	0	. 6	1. 6
Untreated 1963-crop check	4. 2	4. 4	4. 2	4. 4	([3])	([3])
Untreated 1952-crop check	4. 0	4. 4	3. 4	3. 4	4. 2	3. 8
1963-crop check [4]	. 2	3. 8	3. 6	5. 0	5. 0	5. 0
1952-crop check [4]	. 2	1. 8	2. 6	3. 4	3. 4	3. 4

[1] Damage ratings code: 0=no visible infestation; 1=slight damage as evidenced by a few insects and a small amount of insect frass; 2, 3, and 4=ascending numbers of insects and corresponding amount of insect frass; 5=large infestation with great amounts of insect frass and spoilage of grain.

[2] The samples stored for 6 months were rated 135 days, instead of 120 days, after storage.

[3] Samples not retained due to heavy infestations shown in toxicity reading.

[4] Samples not exposed to insects during storage.

than to wheat treated with Kenite 2–I in tests with both insects. The lower dosages of the diatomaceous earths did not protect the wheat as well as the highest dosage. The lesser grain borer progeny caused slightly more damage than the rice weevils did.

Most of the samples of wheat treated with silica aerogel were heavily damaged after only 1 month of storage before sampling. The samples taken after 9 months' storage were so heavily damaged in the bioassays that they were not available for testing of progeny damage.

Malathion protected the wheat completely from damage in the samples stored 6 months or less, but after that some damage by the lesser grain borer and considerable damage by the rice weevil became evident.

The untreated 1952-crop wheat was heavily damaged by the rice weevils and somewhat less so by the lesser grain borers. The samples of the 1963-crop wheat that had not been treated were almost completely destroyed in a few months.

Grade of Grain

The 1963-crop wheat without the inert dust applications (check lots and lots treated with malathion) graded No. 2 and 3 Yellow Hard Winter (YHW). Wheat treated with the silica aerogels graded Sample Grade immediately after treatment because of the presence of foreign substances which rendered it distinctly low quality (DLQ).[3] The diatomaceous earths measurably reduced the test weight, and wheat with these treatments graded No. 4 YHW (table 14). The final observations for grade were made at the end of 12 months.

The untreated 1952-crop wheat initially graded Nos. 1 and 2 Yellow Hard Winter and Hard Winter, but damage by insects during storage reduced the test weight and quality considerably. The grade "Sample, Yellow Hard Winter (Weevily)" was given to all bin samples 12 months after the test began.

After treatment with the dusts there was no further change in grade during 1 year's storage. However, all bins became weevily. Malathion-treated wheat dropped from the initial grade of No. 3 Yellow Hard Winter to Sample Grade (Weevily) during storage. Samples from all bins except those treated with the diatomaceous earths acquired a sour odor.

Chemical, Milling, and Other Tests

Chemical, milling, rheological, and baking tests were made to determine what effect, if any, the different insecticide materials and lengths of storage had had on the wheat and flour (tables 15 to 17). After the wheat was treated, samples large enough to be representative of the wheat in each bin were taken.

The marked reduction in the test weights of the wheat treated with the two diatomaceous earths and the two silica aerogels had no apparent influence on the yield of flour (tables 10 and 15). Normally, the test weight is considered to indicate the flour yield of wheat. The plumpness, moisture content, and other inherent characteristics of the kernels were not basically altered by the addition of these dusts. The dusts did, however, alter the number of kernels per given volume.

Bread-baking properties were tested by two methods. There were no important differences in the initial tests in loaf volume or crumb color and grain of bread from the treated and untreated wheats (table 17). There was no change in the bread-baking characteristics of the samples stored 12 months, with three possible exceptions. In the untreated check sample and two of the treated wheats (Cab-O-Sil and malathion) the crumb grain decreased a moderate amount. The diastatic activity (maltose), flour ash, and protein content of all treated and untreated wheat lots were unchanged by 12 months' storage (tables 15 and 16). Furthermore, the inert dusts did not appear to have reduced the fat content of the treated and stored samples, as compared with the untreated check sample.

The fat acidity values, farinograms, and sedimentation values were not materially changed by the addition of the insecticidal materials nor during the first 6 months' storage. However, significant changes did occur in this same period of time in the capacitance resistance (CR) and the glutamic acid decarboxylase activity (GADA) values. The method of using capacitance resistance measurements (*2*) is based on the moisture distribution within the grain kernel and has been found to be an accurate and rapid indicator of drying damage

[3] See "Grading of Grain Containing Foreign Substances," in the Appendix.

TABLE 14.—*Summary of the official grade determinations of insecticide-treated wheat immediately after treatment and after 12 months' storage*

Insecticide and dosage per 1,000 bushels	Official determination of grade [1]		Samples with live insects		Odor		Moisture		Test weight per bushel	
	After treatment	After 12 months [2]	After treatment	After 12 months	After treatment	After 12 months	After treatment	After 12 months	After treatment	After 12 months
Kenite 2–I:			*Number*	*Number*			*Percent*	*Percent*	*Pounds*	*Pounds*
120 pounds	No. 4 YHW.	No. 4 YHW.	0	5	None	None	9.66	11.44	[3]54.96	[3]54.50
210 pounds	do	do	0	5	do	do	9.66	11.34	[3]54.96	[3]54.62
300 pounds	do	do	0	5	do	do	9.58	11.32	[3]54.96	[3]54.64
Perma-Guard:										
120 pounds	do	do	0	5	do	do	9.54	11.46	[3]55.08	[3]55.06
210 pounds	do	do	0	5	do	do	9.54	11.46	[3]54.84	[3]54.60
300 pounds	do	do	0	5	do	do	9.56	11.44	[3]54.74	[3]54.88
Cab-O-Sil:										
15 pounds	Sample YHW.	Sample YHW.	1	5	do	Sour [3]	9.82	12.40	54.86	50.24
30 pounds	do	do	0	5	do	do [3]	9.66	11.82	54.30	51.66
45 pounds	do	do	0	5	do	do [3]	9.40	11.62	54.12	53.14
SG–68:										
15 pounds	do	do	0	5	do	do [3]	9.78	12.58	54.92	49.80
30 pounds	do	do	0	5	do	do [3]	9.52	11.82	54.28	50.88
45 pounds	do	do	0	5	do	do [3]	9.48	11.48	54.08	52.40
Malathion, 57 pct. e.c., 1 pint.	No. 3 YHW.	do	0	5	do	do [3]	10.00	12.12	58.20	54.82
Untreated 1963-crop check.	No. 2 YHW.	do	3	5	do	do [3]	10.26	12.40	58.36	48.60
Untreated 1952-crop check.	No. 1 YHW.	do	2	5	do	do [3]	10.68	11.92	59.72	54.92

Insecticide and dosage per 1,000 bushels	Foreign material		Damaged kernels		Insect damage		Shrunken and broken kernels after 12 months	Dockage		Total defects after 12 months
	After treatment	After 12 months	After treatment	After 12 months	After treatment	After 12 months		After treatment	After 12 months	
Kenite 2–I:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
120 pounds	1.28	1.16	0.22	2.80	0.02	2.20	2.14	0.70	0.10	6.10
210 pounds	1.14	.88	.04	2.40	.02	1.70	1.94	.60	.20	5.22
300 pounds	1.08	1.06	.24	1.98	.04	1.38	2.10	.44	.10	5.14
Perma-Guard:										
120 pounds	.86	.68	.14	4.34	.02	3.98	2.30	.52	.40	7.32
210 pounds	1.24	.98	.20	3.40	0	2.80	2.50	.74	.40	6.88
300 pounds	.86	.84	.02	2.80	.02	2.56	2.52	.58	.30	6.16
Cab-O-Sil:										
15 pounds	.76	.36	.06	[3]20.90	.04	20.40	1.84	.54	.80	[3]22.72
30 pounds	.70	.66	.18	12.40	0	12.00	2.44	.52	.50	15.50
45 pounds	.72	.78	.06	6.10	.02	5.90	3.00	.56	.50	9.88
SG–68:										
15 pounds	.62	.60	.20	13.00	.02	12.80	2.62	.48	1.00	16.22
30 pounds	.76	.80	.46	[3]20.80	.02	20.80	2.74	.60	.90	[3]24.32
45 pounds	.56	.86	.06	9.20	0	9.10	3.08	.66	.80	13.14
Malathion, 57 pct., e.c., 1 pint	1.32	1.18	.24	[3]16.30	.06	15.90	2.98	.46	.80	[3]20.46
Untreated 1963-crop check	.70	.36	.34	[3]28.60	0	27.70	1.94	.52	.30	[3]30.90
Untreated 1952-crop check	.30	.28	.64	14.40	.48	13.50	3.04	.24	.50	17.72

[1] YHW—Yellow Hard Winter; HW—Hard Winter.
[2] All samples were weevily.
[3] Primary factor influencing grade.

TABLE 15.—*Analysis of 1963-crop wheat samples collected immediately after insecticide treatment and after 6 and 12 months' storage in small bins*

Treatment and time test was made	Test weight [1]	Flour yield [2]	Moisture	Protein [3]	Sedimentation [3]	Fat acidity [4]	Fat content [2]	CR [5]	GADA [6]
Untreated check									
	Lb.	*Pct.*	*Pct.*	*Pct.*	*Ml.*		*Pct.*		*Cm.*
Before storage	58.8	76.3	10.5	10.7	28	15	1.86	0	12.3
Stored 6 months	58.6	76.0	10.8	10.6	26	15	2.06	7.5	6.1
Stored 12 months	55.5	74.2	12.1	10.7	24	34	1.92	7.5	4.4
Cab-O-Sil, 30 pounds [7]									
Immediately after treatment	54.6	75.6	9.9	10.5	27	14	1.68	5.0	13.1
Stored 6 months	55.8	75.8	10.8	10.6	27	15	1.89	14.0	4.9
Stored 12 months	54.0	72.8	12.1	10.8	23	36	1.93	12.0	7.2
SG-68, 30 pounds [7]									
Immediately after treatment	54.7	75.1	10.0	10.4	26	14	1.80	6.0	11.1
Stored 6 months	56.0	75.5	10.8	10.6	26	15	1.83	16.0	5.2
Stored 12 months	54.9	73.2	12.1	10.5	22	24	1.94	11.5	6.8
Perma-Guard, 210 pounds [7]									
Immediately after treatment	55.2	75.6	10.1	10.5	27	12	1.84	5.0	12.0
Stored 6 months	55.8	76.0	10.8	10.7	27	15	1.90	14.0	5.5
Stored 12 months	54.9	73.7	12.0	10.5	23	21	2.00	13.0	7.3
Kenite 2-I, 210 pounds [7]									
Immediately after treatment	55.2	75.3	10.1	10.6	27	12	1.73	4.5	13.5
Stored 6 months	55.7	75.1	10.9	10.7	27	16	1.84	14.5	5.7
Stored 12 months	54.6	73.9	12.1	10.6	24	20	1.91	14.0	8.1
Malathion, 1 pint [7]									
Immediately after treatment	58.7	76.4	9.8	10.4	27	15	1.85	0	12.7
Stored 6 months	59.2	75.3	10.3	10.5	28	14	2.07	8.0	6.2
Stored 12 months	57.1	74.1	12.1	10.7	22	25	2.00	9.0	7.1

[1] Dockage-free.
[2] Moisture-free basis.
[3] 14.0-percent moisture basis.
[4] Milligrams of potassium hydroxide per 100-gram sample (moisture-free basis).
[5] Capacitance resistance.
[6] Glutamic acid decarboxylase activity.
[7] Dosage per 1,000 bushels.

in corn. This test is relatively new and will require more data for evaluation. The CR test was included in this study to evaluate its use as a measure of deterioration in wheat. The GADA test (*7*) is related to the enzymatic activity of wheat. It is claimed to be a quick and reliable method of estimating the quality of stored cereal grains. The first 6 months of storage caused marked increases in the CR readings and considerable reductions in the GADA values for all the treated and the untreated samples. These two tests showed no important changes in the wheat during the last 6 months of storage.

Sedimentation values decreased slightly in all treatments during the last 6 months of storage. Some of the losses were not significant, but they do indicate a trend. The fat acidity values for all samples definitely increased during the last 6 months of storage. Wheat from the untreated 1963-crop check and the Cab-O-Sil treatment showed the greatest fat acidity increases.

The dough (rheological properties) tests showed that the mixing tolerance—as measured by the farinograph—of wheat initially treated with Kenite and Perma-Guard and stored for 12 months did not change. The mixing tolerance values from all the other wheats increased during the final 6 months of storage. Although small, these increases, which are favorable, indicate a trend. Mixing tolerance (stability to mixing) is an important characteristic of flour of interest to the baker.

TABLE 16.—*Analysis of flour from 1963-crop wheat samples collected immediately after insecticide treatment and after 6 and 12 months' storage in small bins*

Treatment and time test was made	Ash [1]	Diastatic activity [2]	Farinograph characteristics			
			Mixing tolerance	Mixing peak	Valorimeter value	Absorption
Untreated Check	*Pct.*	*Mg.*	*Min.*	*Min.*		*Pct.*
Before storage	0. 51	149	4. 50	2. 00	48	57. 0
Stored 6 months	. 50	158	6. 00	1. 50	50	55. 4
Stored 12 months	. 51	147	11. 00	1. 50	54	56. 9
Cab-O-Sil, 30 pounds [3]						
Immediately after treatment	. 50	147	5. 00	2. 50	49	56. 7
Stored 6 months	. 50	152	6. 75	1. 75	48	55. 7
Stored 12 months	. 49	143	10. 50	2. 00	49	56. 8
SG–68, 30 pounds [3]						
Immediately after treatment	. 50	144	3. 00	1. 75	46	56. 3
Stored 6 months	. 52	152	3. 75	1. 50	44	56. 3
Stored 12 months	. 49	151	9. 50	2. 00	45	56. 5
Perma-Guard, 210 pounds [3]						
Immediately after treatment	. 50	145	5. 00	2. 00	48	56. 3
Stored 6 months	. 54	156	6. 00	1. 75	48	56. 6
Stored 12 months	. 49	135	5. 50	1. 50	51	56. 1
Kenite 2–I, 210 pounds [3]						
Immediately after treatment	. 49	145	3. 50	2. 00	48	56. 3
Stored 6 months	. 51	148	3. 50	1. 50	48	55. 6
Stored 12 months	. 48	130	2. 50	1. 75	50	57. 0
Malathion, 1 pint [3]						
Immediately after treatment	. 49	146	4. 25	2. 00	46	59. 6
Stored 6 months	. 48	155	4. 25	1. 50	45	55. 4
Stored 12 months	. 46	151	8. 50	2. 00	45	57. 2

[1] 14.0-percent moisture basis.
[2] Calculated as maltose content. Milligrams per 10 grams of flour.
[3] Dosage per 1,000 bushels of wheat.

The test weight of the wheats during the first 6 months of storage was unchanged, but during the last 6 months, significant losses of weight from weevil infestation occurred in the control and, to a lesser extent, in the malathion-treated samples. Less intense infestations were noted in wheat treated with the silica aerogels. No live weevils were found in the samples of wheat treated with the diatomaceous earths.

FINDINGS

The protectant properties of three dosage levels of two diatomaceous earths and two silica aerogel dusts were compared with those of the standard malathion emulsion treatment. Results during the study were remarkably consistent between replications of individual treatments. Also, there was good correlation between results of the different methods of evaluation of the effectiveness of individual treatments.

The following conclusions were drawn:

(1) The diatomaceous earths at dosages of 120, 210, and 300 pounds per 1,000 bushels protected the quality of the wheat better than the malathion application after storage of more than 6 months.

(2) The silica aerogels at dosages of 15, 30, and 45 pounds per 1,000 bushels gave unsatisfactory protection, although results from the 45-pound dosage indicated that they might be effective at higher dosages.

TABLE 17.—*Bread baking tests with 1963-crop wheat samples collected immediately after insecticide treatment and after 6 and 12 months' storage in small bins*

Treatment and time test was made	Rich formula with DSM [1]					Rich formula without DSM [1]		
	Absorption	Dough mixing time	Loaf volume	Crumb color	Crumb grain	Loaf volume	Crumb color	Crumb grain
Untreated check	*Pct.*	*Min.*	*Cc.*	*Score* [2]	*Score* [2]	*Cc.*	*Score* [2]	*Score* [2]
Before storage	63	3. 75	683	70	80	603	65	75
Stored 6 months	62	3. 25	685	65	85	570	70	70
Stored 12 months	62	4. 25	690	70	75	608	60	55
Cab-O-Sil, 30 pounds [3]								
Immediately after treatment	61	3. 75	670	75	70	588	65	65
Stored 6 months	62	3. 50	650	70	80	555	70	65
Stored 12 months	63	3. 75	695	80	75	600	60	45
SG–68, 30 pounds [3]								
Immediately after treatment	62	3. 75	645	65	75	570	65	65
Stored 6 months	61	3. 50	658	70	75	535	65	65
Stored 12 months	63	3. 75	705	70	75	605	65	60
Perma-Guard, 210 pounds [3]								
Immediately after treatment	62	3. 75	645	65	75	565	70	60
Stored 6 months	62	3. 50	655	80	85	560	65	70
Stored 12 months	63	4. 50	680	75	75	565	65	55
Kenite 2–I, 210 pounds [3]								
Immediately after treatment	63	4. 00	660	70	75	530	65	60
Stored 6 months	61	3. 50	663	75	85	550	60	70
Stored 12 months	62	4. 75	678	75	70	545	60	50
Malathion, 1 pint [3]								
Immediately after treatment	62	3. 75	640	70	80	588	70	70
Stored 6 months	63	3. 25	625	75	80	540	70	65
Stored 12 months	63	4. 50	700	65	65	595	60	55

[1] Dry skim milk.
[2] Subjective measurement on a scale of 35 to 100, from the poorest to the best.
[3] Dosage per 1,000 bushels of wheat.

(3) The applications of the four inert dusts reduced the test weight of the wheat about 4 pounds per bushel and consequently lowered the commercial grade.

(4) Wheat with dust treatments did not change numerical grade during 12 months' storage, although all samples were graded "weevily" at that time.

(5) There was little difference in the results from comparable dosages of the two diatomaceous earths.

(6) Of the two silica aerogels, Cab-O-Sil gave slightly better protection than SG–68.

(7) The malathion residues degraded from 8.44 p.p.m. to 2.54 p.p.m. during the 15 months of storage.

(8) Malathion was fairly effective against rice weevils and lesser grain borers in bioassays throughout the storage period. It compared favorably with the median dosage of the diatomaceous earths.

(9) The untreated 1952-crop check wheat was not damaged by insects as much as the untreated 1963-crop check wheat.

The milling and baking tests disclosed that—

(10) The reduction in the test weight of the wheat treated with either type of inert dust did not affect the flour-yielding capacity.

(11) The addition of the dusts to the wheat did not affect the bread-baking properties of the flour.

(12) No changes occurred in the mixing tolerance of flour from samples of wheat treated with diatomaceous earth (Kenite, Perma-Guard) during 12 months' storage, but increases were noted in other samples.

(13) Sedimentation values decreased slightly and fat acidity increased greatly during the 6th to 12th months of storage.

No insect infestations developed in either the treated or untreated wheat in the large field-scale study during the first 15 months of storage, even though artificial infestations were introduced into each bin at the beginning of the test and during the following summer months. Consequently, no comparisons between the small-bin and field-scale studies were made.

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APPENDIX

Characteristics of Inert Dusts

Perma-Guard:	
Moisture .... percent	1.5 to 3.0
Dry density .... lb. per cu. ft.	20.0 to 24.0
Retained on 325-mesh screen .... percent	9.0 to 13.0
Particle size .... microns	.1 to 40.0
Silica (SiO_2), guaranteed .... percent	Minimum 80.0
Cristobalite .... do	Maximum 1.0
Surface area .... sq. cm. per g	20,000 to 30,000
Brightness .... photovolt	60 to 75
Kenite 2–1:	
Moisture .... percent	8
Retained on 200-mesh screen .... do	Less than 3
Retained on 325-mesh screen .... do	Less than 10
Silica (SiO_2) .... do	88
Surface area .... sq. cm. per g	30,000
Brightness .... photovolt	70
pH (approx.)	7
Dry density .... lb. per cu. ft.	Min. 14, Max. 15
Cab-O-Sil:	
Free moisture (105° C.) .... percent	0.2 to 1.5
Apparent bulk density:	
Fluffy grade .... lb. per cu. ft.	2.5 to 3.5
Densed grade .... do	6.5 to 7.0
Bulking value .... gal. per lb.	0.057
Particle size range .... microns	0.015 to 0.020
Silica (SiO_2) .... percent	99.0 to 99.7
Surface area .... sq. meters per g	175 to 200
pH	3.5 to 4.0
Color	White
Refractive index	1.55
Specific gravity	2.1
SG–68:	
Bulk density .... lb. per cu. ft.	5
Particle size:	
Average .... microns	3.5
Range .... do	80% less than 5.5
Silica (SiO_2) .... percent	99+
Surface area .... sq. meters per g	300
pH (5% dispersion)	7.4
Color	White
Refractive index	1.46
Specific gravity	2.1

Grading of Grain Containing Foreign Substances

Instructions for grading grain containing foreign substances are given in GR Instruction 918-6 Aux.

1 (*1*). Grain that contains an unknown foreign substance is graded "Sample Grade," except when the foreign substance is identified as a diatomaceous earth. An applicant for inspection of grain that contains or appears to contain diatomaceous earth may file a written application with the grain inspector for an examination to determine the presence of a diatomaceous earth. If the inspector determines that the grain contains no unknown foreign substance other than diatomaceous earth, he will grade the grain as though it contained no unknown foreign substance.

A thorough understanding of the grading instructions is needed before applying a diatomaceous earth to grain. Although diatomaceous earth is exempt from the requirement of a tolerance for residues on stored grain, an established tolerance of 8 p.p.m. of malathion is in effect.

USE PESTICIDES SAFELY

Pesticides used improperly can be injurious to man and animals. Use them only when needed and handle them with care. Follow the directions and heed all precautions on the labels.

Some States have special restrictions on the use of certain pesticides. Before applying pesticides, check State and local regulations.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

U.S. DEPARTMENT OF AGRICULTURE

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